THE WORCESTER SEWAGE

AND THE

BLACKSTONE RIVER.

BOSTON:
Rand, Avery, & Co., Printers to the Commonwealth,
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Commonwealth of Massachusetts.

Hon. R. R. Bishop, *President of the Senate.*

The undersigned, members of the State Board of Health, Lunacy, and Charity, in accordance with chapter 67 of the Resolves of 1881, herewith submit, for the consideration of the General Court, the special report of the Board on the subject-matter of the resolve, together with the reports, estimates, plans, and papers in their possession, which relate to the case.

THOMAS TALBOT.
R. T. DAVIS.
EZRA PARMENTER.
EDWARD HITCHCOCK.
CLARA T. LEONARD.
GEO. P. CARTER.
ALFRED HOSMER.
JOHN C. HOADLEY.

Boston, Feb. 4, 1882.

THE SEWAGE OF WORCESTER.

By chap. 67 of Resolves of 1881, it was made the duty of the Board to examine and consider the question of the disposition of the sewage of the city of Worcester, especially with a view to prevent the pollution of the Blackstone River and its tributaries, and to report its conclusions in print to the next Legislature, with recommendations as to a definite plan for the prevention of such pollution. The Board has attended to the duties thus imposed, and has examined that portion of the Blackstone River of which complaint had been made, and also the sewerage system of Worcester itself. Two hearings have taken place, at which all parties interested were notified to be present; and the Board, as already mentioned, has employed C. F. Folsom, M.D., of the National Board of Health, and J. P. Davis, C.E., of New York. These experts, together with the Health Officer of the Board, H. P. Walcott, M.D., have fully examined the subject of the purification of the Worcester sewage, and, after full consideration, have submitted to this Board the report which appears in the Sanitary Appendix.

The authorities of the city of Worcester and the town of Millbury were invited to employ, at their own expense, such persons as might seem to them best qualified to examine, in their behalf, the matters referred to, and to report to this Board.

The city of Worcester failed to comply with this request. The town of Millbury secured the services of Col. G. E. Waring, jun., of Newport, R.I., whose report has been presented, and is printed in the Sanitary Appendix.

The plan proposed by Col. Waring, in this very interesting and able report, is, in the opinion of this Board, open to the following objections: —

OBJECTIONS TO COL. WARING'S PLAN.

First, That the scheme for dividing the flow of the sewage between two narrow channels, one at each side, with a wider channel between them for surface drainage, — the whole to form a single channel whenever, in times of freshet, the surface drainage may rise sufficiently to overflow the partition walls, — is not satisfactory for the following reasons: —

1. The very important portion of the sewer beneath the road-bed of the Boston and Albany Railroad is, in its present form, barely capacious enough to receive and carry off the storm-flow of Mill Brook. The device recommended would, however it were carried out, impair seriously this capacity, while the cost will be very considerable, — little, if any, less than that of a separate sewer for the sewage proper.

2. Dividing the sewage between two channels must greatly diminish the scouring power of the current, by reducing the flow in each of the open ditches so formed, — ditches open, that is, to the main sewer.

3. The large surface that would become coated with sewer-slime, and be exposed to the air of the main sewer, would also be an objection.

4. The great capacity of the main sewer would still constitute it, as now, a vast receptacle for sewer-gases.

Second, The plan of allowing the sewage to flow off upon low lands, advantageous as it appears, and advantageous as it would be, to avoid pumping, seems to us highly objectionable.

1. It cannot be done except upon swampy land, unable to receive more water without flooding. If ditched, as proposed, the ditches would probably fill with water drawn from the soil. Vegetation could dispose of little more water than it now does, and could do little towards absorbing any of the sewage.

2. There would be no aëration except upon the surface; no alternation of air and water in the same interstitial spaces in the ground; no oxidation of organic matters contained in the sewage.

On the other hand, the plan presented by the expert commission seems to meet the objections above enumerated, with well-considered remedies: —

THE WORCESTER SEWAGE. — CONCLUSION.

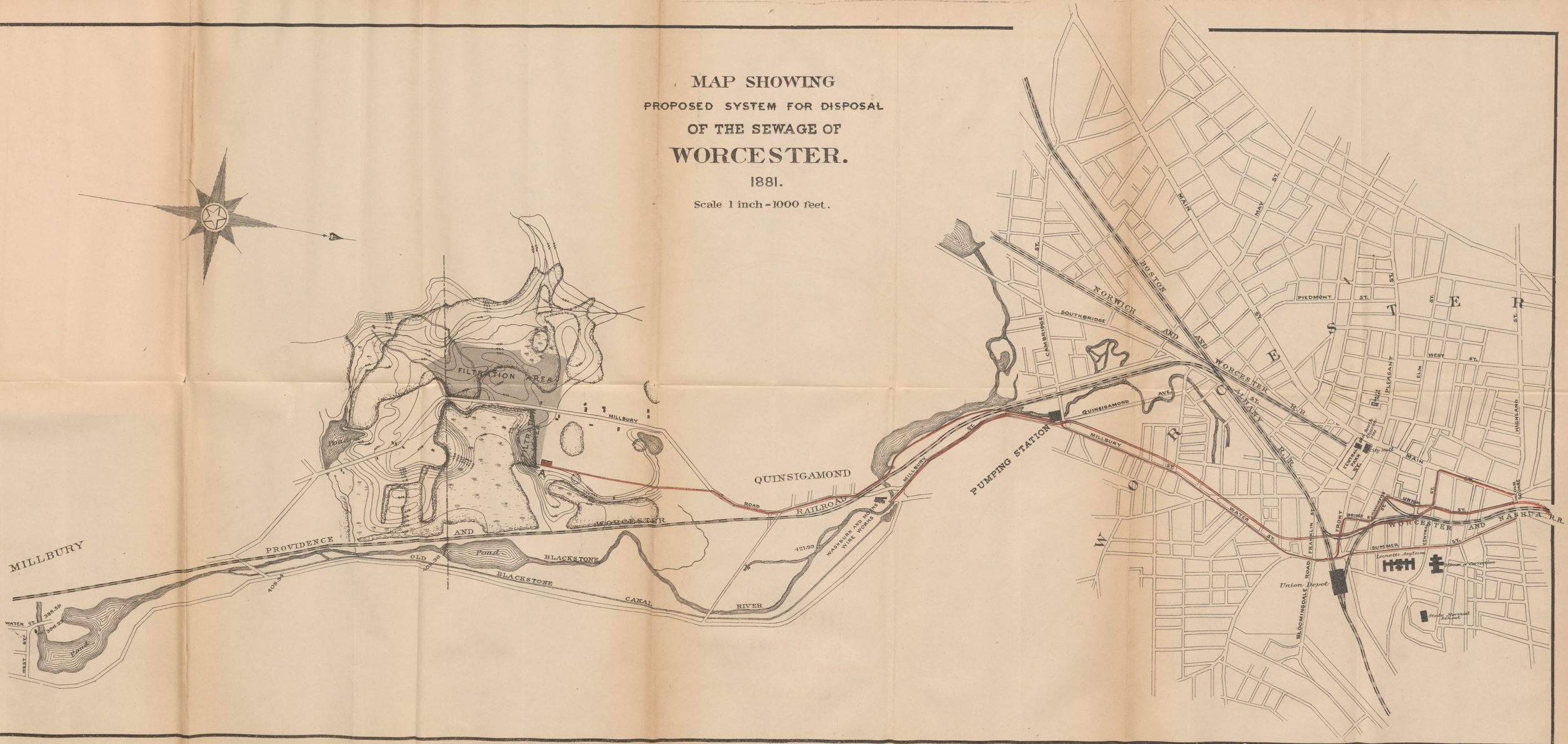
I. Once pumped to a sufficient height, the sewage will flow upon a tract of land of sufficient extent, at such a height above the natural drainage as to give a body of earth, which, when properly drained and prepared, will admit of alternate flow of air and water; of fresh air through well-moistened earth, from which the sewage has recently drained off; of newly supplied sewage through freshly aërated soil, on every side of every pebble, of every grain of sand, of every lump of marl or loam, — thus becoming a portion of the vast lung-surface by which the purification of the sewage is to be brought about through the action of the free oxygen of the air on the oxidizable matter in the sewage.

II. The proposed sewage-pipe must perform perfectly all that the three-channel plan of Col. Waring would, as it seems to us, do less perfectly.

Col. Waring's plan — though it does not, in our opinion, offer so satisfactory a system of irrigation as that proposed by us — brings to this method of sewage-disposal the approval of a very eminent authority in matters of this sort, especially in the light of his own recent critical examination of the most approved methods of drainage both in England and on the Continent. As no plan for the purification of so large an amount of sewage has yet been put in practice in this country, all methods proposed are, to a certain extent, experimental. Still, after mature deliberation, the Board accepts with great confidence the conclusions stated in the report of its experts; being convinced that the system of "intermittent downward filtration," supplemented, if necessary, by broad irrigation, is best adapted to the existing condition of things. And we therefore recommend the system of intermittent downward filtration, submitted in the report of the experts appointed by this Board, as, in the judgment of the Board, the best method of disposing of the sewage of the city of Worcester.

MAP SHOWING
PROPOSED SYSTEM FOR DISPOSAL
OF THE SEWAGE OF
WORCESTER.
1881.

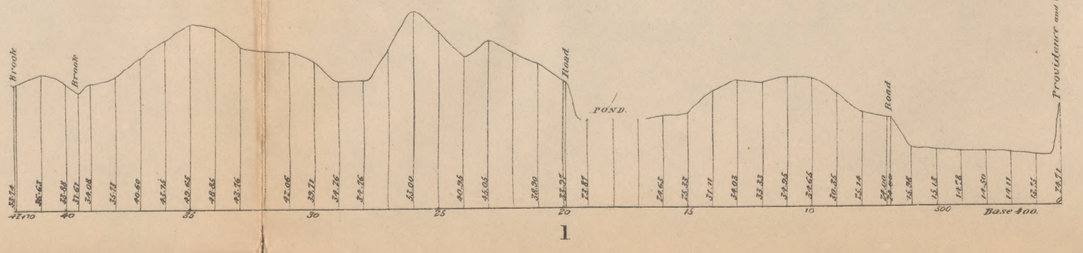
Scale 1 inch = 1000 feet.



Heliotype Printing Co. Boston.

CROSS SECTIONS
of a part of
THE BLACKSTONE VALLEY
SOUTH OF
QUINSIGAMOND VILLAGE

HOR. SCALE 300 FEET TO 1 INCH.
VER " 20 " " " " .



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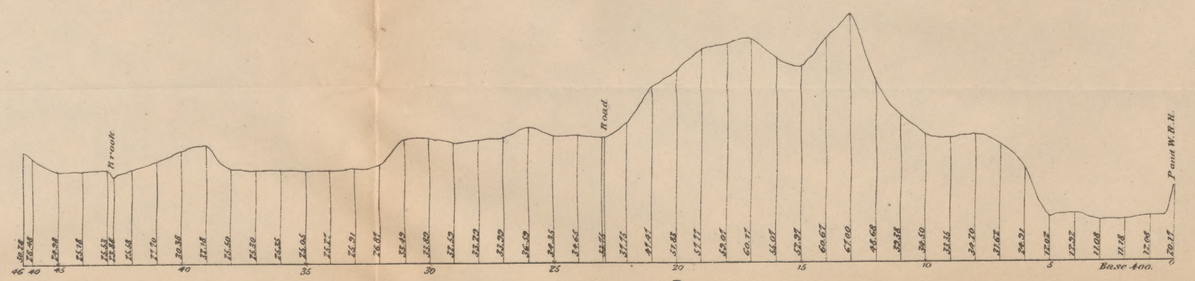

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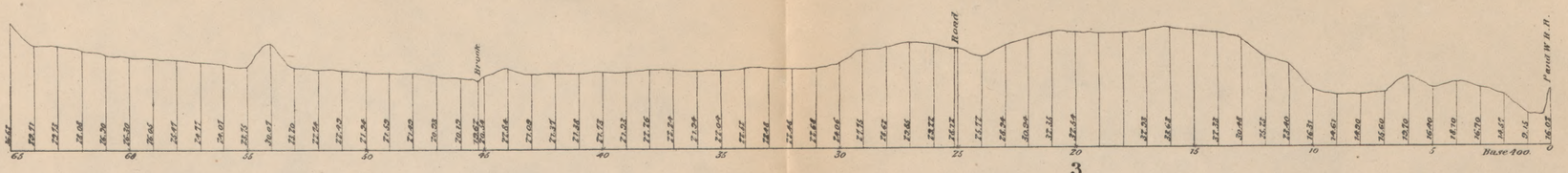

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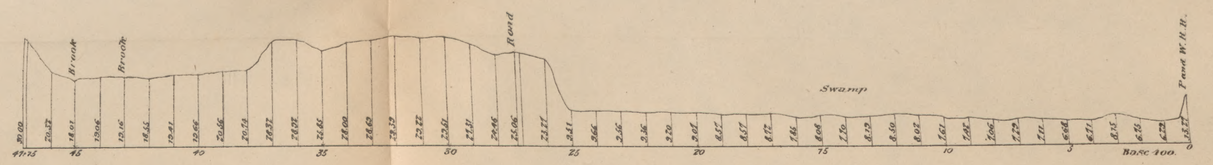

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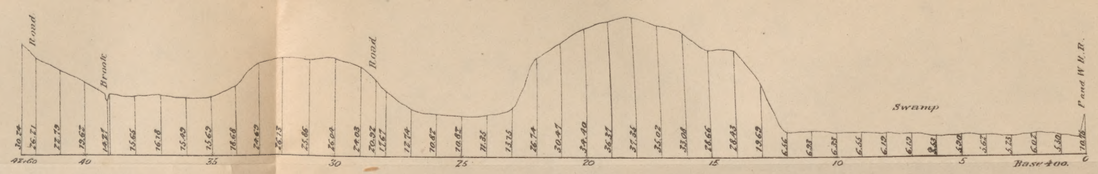

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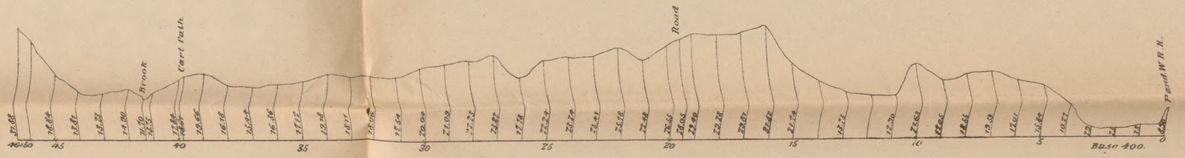

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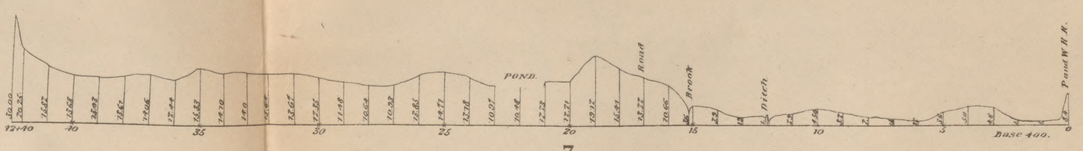

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THE WORCESTER SEWAGE AND THE BLACKSTONE RIVER.

I. — REPORT OF THE BOARD'S COMMITTEE OF EXPERTS.

BOSTON, Nov. 17, 1881.

To the State Board of Health, Lunacy, and Charity.

In conformity to the vote of the Board, July 23, 1881, —

That Dr. C. F. Folsom, Joseph P. Davis, Civil Engineer, of New York, and Dr. H. P. Walcott, Health Officer of the Board, be requested to examine and consider the question of the disposition of the sewage of the city of Worcester, especially with a view to prevent the pollution of the Blackstone River and its tributaries, and report to this committee, —

We have the honor to submit the following report: —

The population of Worcester was, by census, 22,286 in 1855, 24,960 in 1860, 30,055 in 1865, 41,105 in 1870, 49,317 in 1875, and 58,291 in 1880. These figures show an average increase for each five years of a little over 20 per cent, and warn us, that, in designing works for the disposal of the sewage of the city, ample provision should be made for its future growth.

The populated area of the city is now 2,967 acres, of which 1,300 are already sewered; the total length of the sewers, exclusive of the Mill Brook Conduit, being 36 miles.

The average rainfall is 48 inches* annually. The mean temperature (F.) at two points in the State for ten years is as follows, the extremes being from a little over 100°+ to several degrees below zero: —

MONTHS.	CAMBRIDGE Ten Years, 1868-77.	AMHERST. Ten Years, 1868-77.	MONTHS.	CAMBRIDGE Ten Years, 1868-77.	AMHERST. Ten Years, 1868-77.
January	25 3	24.2	August	69 6	69.1
February	25.2	24.5	September	60.9	60.0
March	31.4	31.4	October	49 8	48.4
April	43.2	44.3	November	37.4	37 3
May	55.6	55.0	December	27.5	26.2
June	66.6	67.3			
July	72 3	71.1	Average	47.1	46.6

* The extremes in Boston from 1849 to 1875 were 40.3 and 67.7 inches.

THE BLACKSTONE RIVER AND THE WORCESTER SEWAGE.

The ground freezes from three to five months in the year to a depth varying from one foot to five feet; the snow covers the ground from a few weeks to three or four months, from one foot to three feet deep.

The eastern and most thickly built portion of the city is drained by a considerable stream, called Mill Brook, which, flowing almost due south, empties into the Blackstone River a little above the village of Quinsigamond. This brook receives, along its course, nearly the whole of the sewage of Worcester, brought to it by 44 different sewers. Its drainage area above Lincoln Square is about 8 square miles; above Cambridge Street it has a drainage area of about 12½ square miles. Its average daily dry-weather flow at Cambridge Street, exclusive of sewage, for four months of the year, may be stated at about 3,500,000 gallons, and its minimum daily flow for a single month at 750,000 gallons.

The average gauged flow at Lincoln Square for 79 days in the summer of 1871 was 4,198,000 gallons daily. The flow in times of great freshets may reach the enormous quantity of 1,000,000,000 gallons in 24 hours; but the greatest noted discharge (at Pond Street) was at the rate of 110,000,000 gallons.

The average daily flow for the year is about 13,000,000 gallons.

From the above statement it is evident that, to make practicable any scheme for utilizing or purifying the sewage, it must be intercepted before it reaches the brook.

No extended or reliable gaugings have been made of the dry-weather flow of the sewers. The sewer which enters the brook at Cambridge Street drains what are known as the Island and Piedmont Districts, having a total area of about 670 acres. Mr. Phinehas Ball, former city engineer, in a report made to C. D. Morse, Esq., in this year, estimates the dry-weather flow at about 800,000 gallons daily; and in his opinion, when the Island District is more completely sewered, it will be increased to 1,000,000 gallons. Rough float-gaugings, taken in 1875 from Aug. 26 to Sept. 2, showed the average daily flow of that period to be 1,300,000. The maximum daily flow for that period was 1,463,256 gallons;

and the minimum, 1,135,872 gallons. For the purposes of this report, it is assumed that the dry-weather flow of the sewers of the city is at present 3,000,000 gallons per day, 2,000,000 gallons of which empty into Mill Brook above Cambridge Street, and 1,000,000 gallons at Cambridge Street. Twenty-eight hundred * houses are connected with the present sewers; 4,000 * houses are not connected. There are 26 woollen and cotton mills, beside a few iron-works, saw-mills, grist-mills, a tannery with shambles on the river and its tributaries above the sewer outlet. About 50 gallons of the water-supply are used per individual.

So many samples of the sewage of Worcester were examined by the State Board of Health in 1872, that it is not necessary to repeat the analyses.

Of 27 samples collected from three sewers on eleven different days at six A.M., nine and twelve P.M., the average proportions were, in parts per 100,000, solid residue, 15.29; ammonia, 0.745; albuminoid ammonia, 0.144; chlorine, 3.1. Of 27 samples collected at nine A.M., twelve M., and six P.M., the average was, of solid residue, 25.35; ammonia, 1.876; albuminoid ammonia, 0.316; chlorine, 4.17. The mean of 12 of the first set of samples showed phosphoric acid, 0.1940; and of 12 of the second set, phosphoric acid, 0.6564.

The averages from 50 English cities and towns were, in parts per 100,000, solid residue, 72.2; ammonia, 6.703; chlorine, 10.66. We have, therefore, 3,000,000 gallons of sewage to deal with daily, which the chemical analyses just quoted show to be about twice as dilute as the sewage of English towns, mixed with a brook, whose daily flow ranges from 1,000,000 to 40,000,000 gallons, not including extremes in a rapidly growing city.

Chemical analyses of the water supplied to the river before and after pollution by the sewage of Worcester, made in 1875, showed the following results in parts per 100,000: —

* Approximately.

SPECIAL SANITARY APPENDIX.

	Ammonia.	Alb. Ammonia.	Solid Residue.	Chlorine.
City Reservoir	0.0107	0.0213	4 20	0.18
Mill Brook	0.9600	0.1109	23.44	3.80
Blackstone River, at the sash factory	0 0992	0.0307	8.04	0.92
Blackstone River, below Blackstone Mills	0.0099	0.0139	4.80	0.38

Mill Brook, with its accumulated sewage, empties into the Blackstone River at a point about three miles above the more thickly populated portion (the village) of the town of Millbury. The river flows parallel to and alongside of the main road connecting Millbury with Worcester, and at a point about midway is ponded by a dam. Here a considerable portion of the solids held in suspension are deposited, and a nuisance is created. In the town of Millbury are a number of dams, at each one of which some further deposition occurs; and along the whole course of the stream for some miles below Worcester putrefaction of the organic constituents of the sewage takes place (most rapidly in the summer months), and, as a consequence, offensive gases are liberated, which are largely the cause of complaint of this method of disposing of the sewage.

The deposits undoubtedly stimulate and increase the growth of aquatic plants, and are thus, as well as by their own bulk, hastening the process of filling up the ponds. This, too, is a cause of complaint by the Millbury mill-owners. It is a belief of the people dwelling on and near the banks of the stream, that a perceptible injurious effect upon the general health has been produced, and this belief is shared in, to some extent, by the resident physicians.

That the stream at times is very offensive is quite evident, and that this, in connection with the gradual filling up of the ponds, will soon depreciate the value of property in its vicinity, unless some other than the present method of disposing of the sewage of Worcester is adopted, is beyond question. It should be stated, however, that a not inconsiderable portion of the pollution of the river below Millbury is

contributed by the mills of that town situated on the main stream, and on Singletary Brook.

The stream four miles below the sewer-outlet is unmistakably polluted; twenty-five miles down, the impurity is all but lost to chemical tests. At Millbury the water is unfit for the nicer manufacturing processes, and for boilers, and at times is decidedly offensive.

During the summer of 1881 the following analyses of water, taken in quite dry weather, made under the direction of Professor E. S. Wood, are compared with others in 1872 and 1875 by Professor W. Ripley Nichols in the State Board of Health Report: —

Examination of Blackstone River.

(Parts per 100,000.)

	Date.	Unfiltered.			Residue.			
		Ammonia.	Alb. Ammonia.	Chlorine.	Fixed	Volatile.	Total.	Hardness.
	1872.							
Average of 11 samples, Mill Brook, at Cambridge Street	Oct. –	0 3430	0 2290	2.74	–	–	14.90	–
Average of 12 samples above sewers, Mill Brook	–	0.1970	0.1800	1.62	–	–	15.71	–
	1875.							
Mill Brook, near river	July –	0.9600	0.1109	3 80	–	–	23.44	–
Blackstone River, near sash factory	–	0.0992	0.0307	0 92	–	–	8 04	–
River, near Blackstone Mills	–	0.0099	0.0139	0 38	–	–	4.80	–
River, below dam at Blackstone		0 0157	0.0163	0.36	–	–	4.60	–
	1881.							
Blackstone River, bridge below Perry's Mills, Quinsigamond	Aug. 30	0.9360	0.0858	2.90	5.00	7.50	12.50	3°
Blackstone River, bridge below Perry's Mills, Quinsigamond	Sept. 6	0.3360	0.0882	3.10	8.40	4.00	12.40	3°
Blackstone River, bridge below Perry's Mills, Quinsigamond	11	0.0094	0 1606	3.30	13.30	11.00	24.30	6°
Above Burling Mills	Aug. 30	0 0746	0 0470	2.10	4.00	5 50	9.50	3°
Above Burling Mills	Sept. 6	0.1814	0.1168	3 20	9.50	0.80	10.30	3°
Morse's Mill-pond	Aug. 30	0.0720	0.0690	2 80	8.80	0.90	9.70	3½°
Gowan's Bridge	30	1.1880	0.0334	2.20	9.00	1.90	10.90	2½°

EXAMINATION OF BLACKSTONE RIVER.

Gowan's Bridge	Sept. 6	0.0013	0.2906	4.60	10.00	3.90	13.90	6°
Above Cordis Mills	Aug. 30	1.3230	0.1361	3.00	8.00	4.60	12.60	4°
Blackstone River, above Worcester sewage	Sept. 6	0.0315	0.0261	1.10	5.50	2.10	7.60	1°
Mill Brook, with sewage at Cambridge Street		0.0980	0.3910	7.30	22.10	12.00	34.10	8°
Mill Brook, with sewage at Cambridge Street	Oct. 2	0.1440	0.0186	1.90	8.30	3.70	12.00	2½°
Singletary Brook	2	0.0112	0.0458	0.60	2.50	5.80	8.30	1½°
Blackstone River, below Singletary Brook	2	0.1546	0.0332	1.80	7.60	3.70	11.30	2½°
Blackstone River, above Singletary Brook	2	0.0866	0.1662	2.00	10.80	5.80	16.60	3°
Below Boston and Albany Railroad, and above Fox Village	27	0.5060	0.1100	5.20	21.90	5.10	27.00	9°
Junction of Mill Brook and Piedmont sewer	27	0.6400	0.2400	8.30	26.30	12.50	38.80	8°
Lynde Brook, above South Worcester Wire Mill and below Worcester Carpet Company	27	0.0370	0.0210	0.80	3.40	0.90	4.30	1°
Mouth of sewer at Quinsigamond Village	27	0.9100	0.1700	9.30	30.40	7.00	37.40	8°
Above Burling Mills	27	0.3070	0.0370	2.90	9.20	2.20	11.40	3°
At Morse's Bridge, in front of factory	27	0.0470	0.1410	2.90	8.40	3.70	12.50	3½°

SPECIAL SANITARY APPENDIX.

Comparing the results from the several examinations in 1881 with these of the State Board of Health in 1872, it is clear that the pollution of the stream has increased since that time. As compared with the chemical examinations made by the Board in 1875, there is also an increase, although much less marked. The sewage deposits have been to a certain extent swept away by freshets from time to time, and have not been augmented, except possibly above the dam of the sash factory in Millbury, so considerably as to be of themselves the nuisance that might have been expected.

Considering the extreme heat and cold of the climate, the heavy rainfall, and the great dilution of the sewage, the difficulties in the way of a satisfactory disposal of the sewage of Worcester are far beyond those of any other town where the question has already been met: so that any scheme that may be proposed may be said to be experimental to a certain extent; and to be successful, and not create a greater nuisance than it abolishes, it must be costly in the original outlay, and involve also a considerable yearly expense.

Various methods of preventing the excessive pollution of streams have been adopted or experimented upon in England. They may be classified as follows: —

1. Simple subsidence in tanks.
2. Chemical treatment or precipitation in tanks.
3. Filtration through artificial filters.
4. Intermittent filtration through natural soil.
5. Broad irrigation.

The first and third are very generally abandoned. They simply remove floating solids, leaving all the putrescible solubles to beget a nuisance when putrefaction begins.

The second method produces an effluent which may be allowed to enter most streams that are not afterwards used as a source of water-supply, and is one that a number of towns are constrained to adopt for want of land proper for filtration or irrigation. It removes all the solids, and a small percentage of the soluble elements; and the chemicals used in the various processes tend to fix the remaining putrescible elements in various degrees. Over sixty different precipitation processes have been proposed.

TREATMENT OF SEWAGE IN ENGLAND.

The cheapest one is that known as the lime process, in which about one ton of lime is added to each million of gallons of sewage of the English standard of dilution.

The sewage is then allowed to flow very slowly through a series of carefully constructed tanks in which the floating solid matter, and that produced by the chemical action of the lime, are deposited, forming what is technically termed "sewage sludge." When the sludge has accumulated to a few inches in depth, the supernatant liquid is carefully drawn off, and allowed to flow over irrigation fields or into the neighboring stream. The sludge, consisting in this state of 90 per cent of water, is removed (usually by pumping), and is finally disposed of in some way. After being exposed to the air for a year in the climate of England, it still contains 70 per cent of water.

It may be allowed to accumulate on the land, or it may be dug into the soil to serve as a manure. It is usually given away, or sold (if possible) when partially dried. It is sometimes artificially dried at great expense, when its bulk is so reduced that it becomes a salable manure.

In some towns in England the farmers pay a shilling or two a ton for the air-dried sludge at the leisure time of the year; in others they will not cart it away when given to them.

There are many other chemicals than lime in use in the precipitation processes, many of which produce a slightly better effluent, and a more valuable sediment (if a comparison of the value of materials that are practically worthless may be made), and much less of it. In these respects they are to be preferred; but under most circumstances they are more costly. Where the sludge can be allowed to accumulate without causing a nuisance, the lime process will usually be adopted, although the effluent still contains a considerably greater portion of the putrescible element than in other processes.

Where possible, this effluent should in all precipitation processes be passed through the soil before entering the stream.

For the treatment of the dry-weather sewage of Worcester,

we may assume, in the absence of actual experiments, that between two and three tons of lime per day would be required; that from forty to sixty tons of wet sludge, with 90 per cent of water in it, will be produced daily; and that the cost, exclusive of interest on cost of works, would be from $10,000 to $15,000 per year. This is under the assumption that the sludge is allowed to accumulate, or is given away. It is not probable that it could be sold, unless first treated by some process, which would be at a loss.

To create no nuisance in hot weather by any precipitating process is simply impossible; but the stench need not at any time be a serious matter to the town if the works are a mile or two distant. It can safely be said that nothing but a large expenditure originally, extreme care, and a liberal appropriation each year will prevent a nuisance from being established, if this method be adopted. The resulting "cleansed" water, not having removed from it the soluble filth, decomposes, and creates offensive smells, unless still further purified by running it over land in irrigation. The whole process is quite incomplete, so far as purification of streams is concerned; and on account of its much greater expense than that of irrigation is justifiable only where something must be done, and enough land cannot be got for irrigation.

The fourth method, or that of intermittent filtration, is usually employed, when at all, as an auxiliary to broad irrigation.

It consists, *per se*, in passing intermittently as large volumes of sewage through carefully prepared land as can be made to pass and produce a satisfactory effluent. In most cases, where any considerable area is acquired for the purpose, the net loss is diminished by cultivating crops, as that cannot be done where the greatest amount of sewage that can be filtered is used.

The land, no matter how porous naturally it may be, is thoroughly underdrained; and to get the best results the surface must be shaped to level terraces. If crops are to be grown, it should be further prepared in ridges and furrows, — the former for the growth of the crops, the latter for the distribution of the sewage to their roots.

Intermittent downward filtration has been adopted in Merthyr Tydvil in Wales; but it has been there abandoned in favor of ordinary surface irrigation and modified intermittent downward filtration, as no crops of value could be raised where the amount of sewage per acre (100,000 gallons daily) is so great. It is very seldom that land can be found porous enough for that method of disposing of sewage, there being only one town (Kendal in England) where any considerable quantity of sewage (nearly a million gallons daily on five acres) is now treated to the full extent in that way. Intermittent downward filtration differs from ordinary sewage irrigation simply in the extremely porous character of the soil selected, in the great amount of sewage used per acre, and in the abandonment of any attempt to raise crops of any real value; although, by taking more land than was at first designed by Denton, the amount of sewage used to each acre may be so moderate in amount that excellent crops can be raised: and this has actually been the practice in several towns that have recently adopted intermittent downward filtration in England, of which Abingdon is perhaps the best illustration.

The theory of the process is well described in the report of the English Rivers Pollution Commission, that such a filter is not a mere mechanical contrivance: it is a machine for oxidizing, and thus altogether transforming, as well as for merely separating, the filth of dirty water. A field of porous soil irrigated intermittently virtually performs an act of respiration, copying, on an enormous scale, the lung-action of a breathing animal; for it is alternately receiving and expiring air, and thus dealing as an oxidizing agent with the filthy fluid which is trickling through it. A sufficient extent and depth of porous soil having periodical intervals of rest, during which the soil drains itself, and becomes refilled with air, certainly must be the best possible strainer, oxidizer, and filterer of water containing nauseous organic impurities, both suspended and dissolved.

At Quinsigamond there is an area of land fairly well suited for modified intermittent filtration of sufficient extent to dispose of all the sewage of Worcester, as will be seen by refer-

ence to the accompanying map. The results of this method, so far as the quality of the effluent is concerned, will be quite satisfactory; and, without doubt, the yearly loss will be very much less than with the precipitation process. If intelligently managed, the crops should partly repay the cost of labor and pumping, and possibly also in good years the whole of it, inasmuch as we propose distributing only 40,000 gallons of sewage to the acre, or one-fifth as much as is the practice in Kendal, but about twelve times as much as could be used in ordinary surface irrigation.

The fifth method, or that of broad irrigation, is used with more or less modification, in varying degrees of efficiency, in nearly fifty towns of Great Britain, for about one-eighth of the sewage of the city of Paris, as an important part of the completed portion of the sewerage of Berlin, Stuttgart, and Brussels, and for the disposal of the whole of the sewage of Dantzic in the porous beach-sand of the shore of the Baltic Sea. In no place is there a pecuniary gain from the operation where the sanitary portion of the problem is fairly solved. The yearly deficit varies in Great Britain from a few hundred dollars, or the value of the time of the person directing it, in small towns, to several thousand dollars in the larger places. In Paris and Dantzic it has been impossible for us to get at the profit or loss of the sewage-farming, but the process taken as a whole is quite satisfactory in both those cities.

In Dantzic the contractors for the sewerage of the city were required, as part of their agreement, to dispose of the sewage by irrigation for a period of years. The sewage of Paris constituted from one-twelfth to one-fifteenth of the dry-weather flow of the Seine, being also unusually offensive and with an excessive amount of solid deposit, so that the nuisance was so great as to demand even a costly remedy.

A light loam with a subsoil of gravel is best adapted to the purpose of sewage-irrigation, and three hundred acres of it may be made to sufficiently cleanse 1,000,000 gallons of sewage daily. With that quantity, however, it would be often necessary to pour the sewage on the land when the soil was already wet enough, or even too wet, for the crops,

SEWAGE-FARMS.

so that agricultural loss would be the result; and in heavy rains it would not be always possible to purify at all the sewage, which would simply flow over the land to the nearest stream.

With less than three hundred acres of land to every million gallons of sewage, any crops but grass might be almost ruined in a wet season, unless the excess of water and some of the sewage could then pass into some stream; and it must be a matter of experiment whether there would be any nuisance in case of an extremely hot day following a long-continued rain. To fully satisfy the agricultural part of the problem, one thousand acres should be provided for each one million gallons of daily sewage, although a fair result may be got with a far less area. At best, no one plot of land should be irrigated more than one day in eight in favorable weather. In time of wet soil, any crops except coarse grass, of course, would be injured by pouring additional water upon the ground; and the quantity of coarse grass that can be raised on a sewage-farm with profit is limited to the amount that may be cut and fed fresh to live stock. A dairy farm is the best use possible of sewage-irrigated land, if it be near a large city where milk finds a ready sale.

On an ordinary sewage-farm all crops may be raised. A large hotel in Paris is supplied with fruits and vegetables of the best quality from the sewage-farm at Gennevilliers, and, commonly speaking, the products of them find ready sale.

All sewage-farms that are not managed with care are nuisances. There should never be excessive nuisance; and offensive odors can be avoided in the climate of England, as they can probably also be prevented here, if sufficient land is available.

The best practicable treatment of the difficulty is upon the principle adopted for Paris; and this can be made satisfactory from all points of view, except that of profit. The plan consists in having a large tract of land upon which the sewage may be poured when that is for the advantage of the crops, and in being able to dispose in some other way of all that is not wanted on the farms.

This other way in Paris now consists in dumping it into

the river Seine. By the new plan it will be conveyed to an immense uncultivated tract of land owned by the State. Neither of these methods would be available for Worcester. We know of no other scheme so practicable as being able to provide for all the ordinary sewage by modified intermittent downward filtration, and procuring several hundred acres, upon which surface irrigation may be attempted, and extended from year to year.

Probably there is hardly another place in the State where the conditions of the problem can be so readily met as in Worcester, to remedy an evil which is fast becoming a general one in Massachusetts. Whatever may be the means adopted to purify the sewage, the first step must be to separate it from the very great, but extremely variable, amount of water uniting with it in the brook, and to provide for the direct discharge of storm-overflows into the stream, thereby involving a considerable outlay of money in so changing the present sewerage system of the city as to fulfil these requirements.

An exact comparison of the annual cost of the precipitating system and of sewage-irrigation is not practicable; the actual facts in these respects, wherever either has been adopted, having been almost always disappointing when compared with the estimates. The difficulties which must be met are new, and their cost must be decided largely by experience. Probably the annual loss by precipitation would be between ten thousand and five thousand dollars. A favorable view of irrigation in Worcester would be that, in the best years, with skilful and economical management, there might be no loss beyond the interest on the cost of the works, and that at most the deficit can hardly be over six thousand dollars a year, pumping included.

To properly dispose of the present sewage of Worcester by irrigation would require nine hundred or a thousand acres of land, which would need to be increased in the near future. Unfortunately so large an area of suitable soil conveniently located is not at command except by expensive pumping. We have therefore considered broad irrigation only in connection with modified intermittent filtration, and simply as a

possible means, to be determined by experiment, of reducing the net yearly loss to the city in disposing of its sewage by the latter process.

We therefore recommend, as the most practicable and least expensive method of disposing of the sewage of the city of Worcester, intermittent downward filtration upon so large an area (75 acres) that the sewage daily distributed per acre (40,000 gallons) will not be large enough to prevent the successful raising of crops.* Ordinary surface irrigation may be applied by private parties so far as that may be of benefit to the crops; the filtering ground, however, always being sufficient to dispose of all the sewage, whether the farmers in the vicinity choose to make use of any of it or not.

As has already been pointed out, to make the success of any method of purifying the sewage of Worcester at all probable, it will be necessary to intercept the sewage of Mill Brook Valley before it is discharged into the brook, as the natural flow of the latter is much too large to be dealt with. After careful consideration, we have concluded to recommend a separate system of sewers for the valley.

This work is incidental to all the schemes herein discussed. By it all the sewage proper of the Mill Brook Valley would be brought to Cambridge Street at the point where that street crosses the brook. At this point nearly all of the drainage of the remaining portion of the city now sewered empties into the brook, as here terminates the main sewer in Quinsigamond Avenue, which drains the Piedmont and Island Districts. In fact, it may be said that here, practically, the whole sewage of the city is concentrated. This fact determines the direction in which space must be sought for the utilization or purification of the sewage, and somewhat simplifies the problem.

A mile below Cambridge Street is that division of the city called Quinsigamond, and in Quinsigamond there is found land favorable either for intermittent filtration or for the disposal of the sludge produced by the precipitation process,

* Very extended descriptions of the various plans of disposing of the sewage of towns are given in the Fourth, Seventh, and Eighth Annual Reports of the State Board of Health, with maps of several sewage-farms, so that it will be superfluous for us to go into that matter again extensively in this.

and in the vicinity is a somewhat limited area that may be availed of for broad irrigation.

The Precipitation Scheme.

There are a number of points below Washburn & Moen's wire-works where precipitation tanks might be built; but, taking into consideration that the tanks should be remote from inhabited and growing districts, and that land favorable for the disposal of the sludge should be convenient to them, the best location appears to be at the point marked A on the accompanying map.

An outfall-sewer, three and one-half feet in diameter, with a grade of one in two thousand, capable, when running full, of conveying about 13,000,000 gallons in twenty-four hours, is to be built from Cambridge Street to the tanks on a line substantially as shown on the plan. It crosses Blackstone River in an iron pipe a little above the dam of Washburn & Moen's mills.

The main sewer of the separate system of Mill Brook Valley is to be brought to its upper end by an iron pipe under Mill Brook; and the sewer draining the Piedmont and Island Districts will be diverted directly into it, having, however, a storm-overflow into Mill Brook.

A series of settling-tanks and the necessary machinery for grinding and mixing the lime, and for handling the sludge, is to be provided at the point A. (See map.)

The approximate estimate of the cost of this scheme is as follows: —

Separate system of sewers in Mill Brook Valley	$181,500 00
Outfall-sewer, including iron pipe, etc.	62,900 00
Tanks, machinery, and buildings	55,000 00
	$299,400 00
Add 10 per cent for engineering and contingencies	29,940 00
	$329,340 00
Land and land damages	14,500 00
Total	$343,840 00

The Intermittent Filtration Scheme.

To reach the land that it is proposed to utilize for filtration, it will be necessary to pump the sewage of the Piedmont and Island Districts a height of about seven feet. The estimate therefore provides for a pumping-station at Cambridge Street with horizontal non-condensing engines and centrifugal pumps. The sewage of Mill Brook Valley can be brought to this point at an elevation that will allow it to flow into the outfall-sewer without pumping. From Cambridge Street, the outfall-sewer, 42″ in diameter, follows the same route (but at a higher grade) as in the precipitation scheme, and terminates in a small subsiding-tank, as shown at A on the plan.

The estimate covers the expenses of thoroughly sub-draining the filtration land to a depth of six feet, the cost of levelling and preparing the surface, clearing and grubbing, and of building a complete system of carriers. It is as follows: —

Separate system of sewers	$181,500 00
Pumping-station	17,500 00
Outfall-sewer, including iron pipe, etc.	55,300 00
Subsiding-tanks	9,500 00
Preparation of land for filtration	72,100 00
	$335,900 00
Add 10 per cent for engineering and contingencies	33,590 00
	$369,490 00
Land and land damages	39,000 00
Total	$408,490 00

The estimated yearly cost of pumping is $3,500.

This scheme is complete in itself, and makes ample provision for the purification of the sewage of Worcester; but should it be thought advisable to supplement it with broad irrigation, with a view to a more complete and better utilization of the sewage, the cost and preparation for irrigation should be added to the above estimate. It would require a more thorough study of the land than we have thought it necessary to bestow, to make a close approximation to this cost; but it may be stated roughly as $100,000.

(Signed) CHARLES F. FOLSOM, M.D.
JOSEPH P. DAVIS, C.E.
HENRY P. WALCOTT, M.D.

SPECIAL SANITARY APPENDIX.

II. — REPORT FROM MILLBURY.

MILLBURY, Dec. 15, 1881.

CHARLES F. DONNELLY, Esq.,
Secretary of the State Board of Health, Lunacy, and Charity.

Dear Sir. — Your communication of the 22d of July, to the selectmen of Millbury, was by them referred to the undersigned, a committee appointed by the town some years since to take into consideration and report upon the matter of the pollution of the Blackstone River by the Worcester system of sewerage. By subsequent votes of the town, this committee has been given full power to act for and represent the town in the matter. In compliance with the request (contained in your communication above referred to) "to furnish evidence of experts and others for the information of the Board," we engaged the services of George E. Waring, jun., of Newport, requesting him to investigate the matter, and furnish us with a plan, to be presented to your Board, for disposing of the sewage of the city of Worcester, so as to prevent the pollution of the Blackstone River; having in view economy in original outlay and subsequent care, effectiveness in results, and the least injury by loss of water to the industries below dependent upon the water-power of the river. The result of his investigation, and his recommendations, embodied in a paper entitled "A Project for the Purification of the Sewage of Worcester," and the accompanying plans transmitted herewith, we respectfully submit for the consideration of your Board. We understand that plans, similar to that proposed by Col. Waring, are in use at the present day at other places where it has been found necessary to prevent the pollution of rivers; and the probability of obtaining satisfactory results may be inferred from the success attained where such a plan has been adopted. Its simplicity and economy in first cost must commend themselves. In matters of detail not affecting the general plan, however, some changes easily effected may seem desirable.

Mr. Waring, although visiting the ground, used, in putting his plan upon paper, data from surveys made under the direc-

tion of your Board. It is possible that the proximity of the mouth of his proposed conduit to the village of Quinsigamond was not called to his attention. To continue the conduit further down, perhaps to the "Market land," would seem desirable in some respects. Should it be desired by your Board, Mr. Waring would be pleased to appear before you, and explain his plan in person. He has arranged, he tells us, to go South soon; and consequently such a meeting must be arranged for an early day, if at all.

In presenting the project of Mr. Waring, we wish to be understood as having no desire to oppose other plans, or to insist upon this, if others seem more promising, either in results as to purification, in pecuniary returns from the production of valuable crops by irrigation, or otherwise. To the city of Worcester a probable return from the investment is a matter of importance, and should have weight, even against a considerable increase in the first outlay. What is desired by the inhabitants of this and other towns along the Blackstone River, is relief from an evil, great at the present time, and threatening to become intolerable in the near future, as the city of Worcester increases in population. As to the means of preventing this evil we have no pride of opinion. Satisfactory results are all we ask for. Called upon by your Board to furnish expert testimony, we have employed one eminent as a sanitary engineer, and submit his recommendations, confident that they will merit the consideration of the members of your Board.

At this time, permit us to refer to a matter which we think ought not to be lost sight of in this connection. Whatever plan may eventually be adopted, there will necessarily result a greater or less loss of water; which, in the dry season of the year, when evaporation takes place rapidly, may amount to so much as to be a serious matter to the mills using the stream for water-power. Even now the loss to manufacturers is noticeable. But it is claimed that whatever water is taken for the Worcester water-supply is returned to the river through the sewers. This can, of course, be true only to a certain extent. With the sewer-water used for irrigation, and restrained for purposes of purification, the loss will be

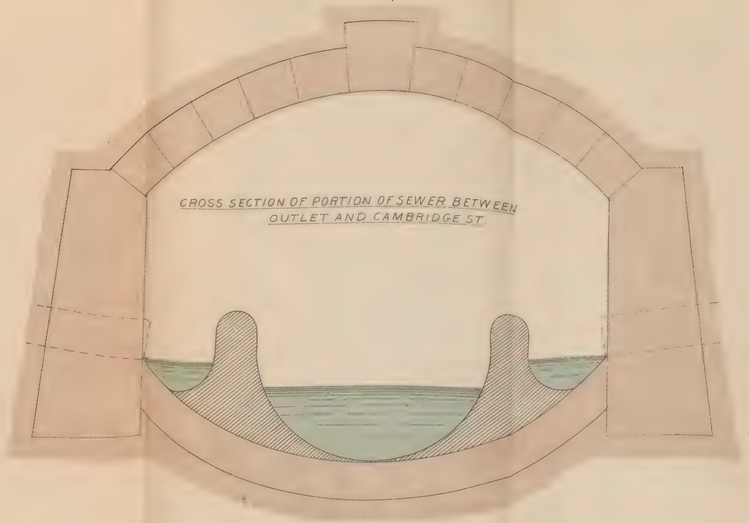
much greater. We would urge the necessity of providing some means to make good this loss. And we respectfully ask that, should your Board report to the Legislature a plan to prevent the pollution of the river, they will also report that by means of additional storage basins, to be used for this purpose, the city should make good the consequent loss of water. For loss of water heretofore diverted from the Blackstone River, no recompense has been made by the city to mill-owners below the mouth of the sewer.

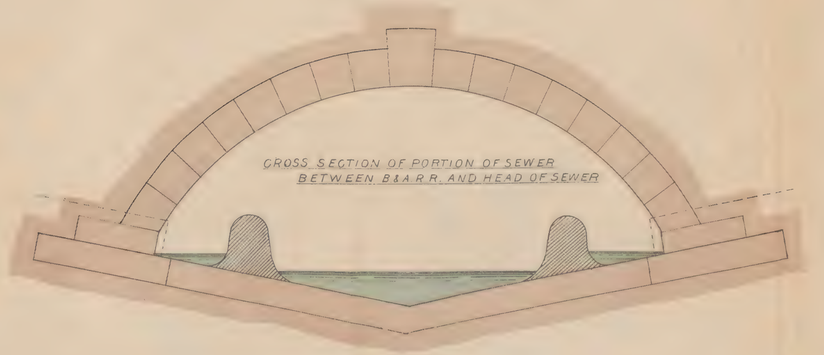
Respectfully submitted.

GEORGE A. FLAGG,
C. D. MORSE,
OSGOOD H. WATERS,
Committee of the Town of Millbury.


CLEAR LAND
PERRY GRIST MILL
1
15 ACRES
2
25 ACRES
CLEAR LAND
WOODS
OPEN GROUND
OUTLET OF SEWER
CLOSED CONDUIT FROM SEWER
QUINSIGAMOND VILLAGE
OUTLET
PROVIDENCE AND WORCESTER R R
GRAVEL PIT
PINE
THICKET AND WOODS
OPEN LAND
OPEN LAND
SWAMP
SWAMPY THICKET
A
42 ACRES
B
42 ACRES
C
42 ACRES
CLEAR LAND
MEADOW
DAM
OUTLET
INNER BROWN LINE SHOWS AREA TO BE CARRIED FROM SEWER BY OUTER BROWN LINE SHOWS AREA TO BE CARRIED FROM SEWER BY MAIN CARRIER BY OPENING GATE No 1 AND CLOSING GATES Nos 2 & 3
ALL LINES IN BROWN SHOW PROPOSED PLAN OF SEWAGE DISPOSAL
PROPOSED PLAN
FOR
SEWAGE DISPOSAL
AT
WORCESTER, MASS.
NOTE: WHEREVER THE WORD "OSIER" OCCURS, READ "WILLOW".
MARKET FARM
LEDGE
POTATOES
OPEN
WOODS
PINE AND OAK
CEDAR SWAMP
BRUSH
BARS
LEDGE CROPPINGS
CLEAR LAND
CRANBERRY MEADOW
HULL PLACE
MILL DAM
HAYDEN
HULLS POND
SCALE
1 INCH = 400 FEET.
400 300 200 100 0 400 800 1200 1600 2000 2400 Ft.

PROPOSED PLAN FOR SEPARATING THE DRY WEATHER FLOW FROM STORMWATER IN THE MAIN SEWER AT WORCESTER, MASS.





III. — A PROJECT FOR THE PURIFICATION OF THE SEWAGE OF WORCESTER.

PREPARED FOR THE TOWN OF MILLBURY BY GEORGE E. WARING, JUN.

General Statement.

As I understand the problem now presented to the town of Millbury, it is to suggest some practicable plan by which the city of Worcester may withhold from the Blackstone River the waste organic matters produced by its population and its industries, and now polluting that stream. This pollution is a nuisance to the occupants of the banks of the river, and the people of Millbury are especial sufferers therefrom.

The right of riparian owners to demand that a water-course be maintained in its original state of purity will hardly be questioned; nor does the duty properly devolve upon them of pointing out the way in which matters defiling it may be diverted. This question has, in the present case, however, an especial interest for Millbury, because its best chance of speedy relief lies in the suggestion of a system of purification, which by its completeness, economy, and simplicity, will commend itself to the prudence and good sense of the offending community as promising, at an inconsiderable cost, the final settlement of a question of serious moment in its future relations with its neighbors.

In attempting to formulate such a system, I have examined carefully many of the existing purification works of England and of the continent of Europe, and have studied the recent literature of the subject. These investigations have seemed to demonstrate, that, for a city circumstanced as Worcester is, none of the so-called "chemical" processes are worth considering; that no form of profitable agricultural use, however great its promise, should now be a controlling aim; and that the main object — the purification of the foul

effluent of the sewers of Worcester — may be attained with certainty and with ease under the peculiarly favorable conditions existing.

In assigning a second place to the very important question of profitable utilization, I hasten to assert my full confidence in its complete and satisfactory solution, even where the conditions are much less favorable than here. My idea is only that it still is a question; that its solution is not yet so general and complete that an American city can be asked to accept it as final; and that the efficiency and economy of the method of purification I am about to recommend is so clearly indicated as to make the demand for its adoption in the present case, or for the adoption of its equivalent, entirely reasonable.

Although, in my opinion, the agricultural aim should not be a controlling one, it should surely be kept constantly in view, and the work should be so planned that agricultural utilization may always be easy. The proposition as it now stands relates to the cheap and efficient withholding from the Blackstone River of the foul wastes of the city, and this is all that the riparian population can exact. The further proposition of turning these wastes to profitable use concerns us all, but especially the people of Worcester, and it should claim our next consideration.

Taking the case as it stands, we find that the costly and elaborate system of sewers of Worcester includes no means for the separation of storm-water and sewage, nor is it worth while to consider such a separation at present. The main sewer has been made to include the channel of Mill Brook, — a considerable stream, which is subject to a large increase of volume during storms. The separation of the waters of this stream during dry weather is easily possible, and such separation is necessary to any economical treatment of the foul effluent. During storms, the lateral sewers being also storm-water sewers, separation is not now practicable, and the storm effluent must continue to reach the river with its burden of filth. At such times, however, the high state of dilution of the sewage, and the increased volume of the river itself, may be trusted for a long time to come to keep the

nuisance within bearable proportions. If all future sewers of Worcester are built on the principle of absolute separation, the relief may remain permanent.

Without reference to a possible future separation of storm-water and sewage in the sewers of the city itself, and accepting as sufficient the dilution of the whole effluent during storms, we must secure the most complete separation possible between the ordinary *brook* flow and the dry-weather discharge of the lateral sewers, both of which now unite to form the current of the main sewer. It has been suggested * that the main sewer be furnished with an iron pipe connected by lateral branches with the mouths of the lateral sewers, each branch being provided with an automatic gate to throw the whole flow into the main sewer itself during storms. On further consideration, it is thought that the same result might be secured by the construction of two longitudinal walls in the main sewer, — one near each side, so as to carry off the dry-weather discharge of the sewers independently, and to furnish a sufficient centre channel for the ordinary flow of the brook. The floors or inverts of the three conduits should of course be carefully formed. During storms the flow would rise above the dividing walls, and the several currents would become more or less intermingled. The outlets of the side channels should be connected with the purification works by some means which, while admitting a considerable increase of flow during the early stages of a storm, when the lateral sewers are being cleansed of their deposits, would, with the increase of the flood, be closed to even less than their ordinary capacity, — sending nearly all of the storm-flow directly to the river. This system would have the advantage of economy and simplicity, and it would secure a complete separation in the absence of storms. This is all that we can now hope to accomplish.

The dry-weather flow of the city sewers being thus separated from the waters of Mill Brook, and so brought within reasonable limits, it should, at the present outlet, be taken up by a covered conduit and carried to a point suitably dis-

* A Report upon the Possibility of utilizing the Sewage of Worcester, by Phinehas Ball, 1873.

tant. At this point it should be received in a twin chamber, either compartment of which should be large enough to cause a deposition of earthy matters only, and not large enough to allow the subsidence of any considerable amount of organic matter. For the removal of the accumulated earth the flow could be diverted from one compartment to the other.

Each chamber should be provided with two screens, one with two-inch openings to keep back coarse rubbish, and one with one-half inch openings to arrest the remaining solids. These solids should be raked out daily and composted, or otherwise treated. Experience at the screening-chambers in Berlin indicates that the quantity of these matters will be trifling.

After screening, the sewage containing its dissolved and suspended impurities undiminished, must be subjected to such treatment as will rob it of all these, and deliver it to the Blackstone River in a purified condition.

Purification Works.

The data at hand — chiefly the survey made for the Board of Health — do not furnish a sufficient basis for a precise detailed scheme. They will serve, however, for the general determination of a process which can be adapted in all its parts to the exact conditions that further surveys may establish. The following, with this reservation, is submitted as a practicable scheme for the treatment of the sewage of Worcester: —

We will assume the closed conduit to be continued for a distance of about 2,500 feet from the present outlet, mainly on the west side of the river, with a fall of 1 in 1,000. From its mouth to the beginning of the field-work (a distance of 500 feet), the conduit should be a wooden trough having a fall of 1 in 250, and wide enough to carry the ordinary flow at such a fall with a depth of less than one inch. For a further short distance the same conduit should continue on a level grade, delivering its checked flow into the main trench of the purification works.

The sewage is now cleansed of its coarser objects and of

PURIFICATION OF THE SEWAGE OF WORCESTER.

its sand; its suspended matters have been comminuted by its rapid descent down the 500-foot incline, and it has become thoroughly aërated. It is, in short, in the best condition for the subsequent treatment proposed for it.

The land to be employed for this treatment includes all the area between the Providence and Worcester Railroad and the 412-foot contour line (about 130 acres) and two tracts of about 15 acres each lying north of this area, on the east side of the railroad; making in all about 160 acres more or less. The irregular area has been very roughly calculated; but precision is of no consequence: the amount of land is more than ample.

The method adopted combines a long, sluggish flow in ditches, between banks planted with vigorous, water-loving vegetation, and a long exposure to the air; together with a broad surface-flow over a series of extensive beds for the final purification of so much of the effluent as has not been evaporated during the long exposure over an extended surface, and by the leaves of the plants and trees grown.

In the accompanying sketch, Nos. 1 and 2 are two tracts of about 15 acres each, laid off in alternate ditches and banks, the ditches connecting alternately at each end of the field, so as to form a continuous channel from the entrance to the exit, the banks projecting between its loops from one side of the field and from the other by turns.

Except for a short distance at the beginning, where greater velocity is desirable, the ditches are 6 feet wide, and 2 feet deep from the water-line.

The banks are 10 feet wide, and 1.2 feet high from the water-line.

After making allowance for headlands, etc., each acre will give about ½ mile of ditch, or about 7½ miles for each 15-acre tract.

The sides of the banks — leaving a passage-way in the centre — may be planted either with osier-bushes or with willow-trees, or with both according to the promise of the market. Willows growing under such circumstances would produce a heavy burden of valuable pollard-lops, while the osier product would be well suited for the finer sorts of basket-

work. Either plant would exercise a marked purifying effect on the stream from which it fed.

Letters A, B, and C indicate three tracts of about 42 acres each, separated from the higher land, — first by a ditch to cut off the surface and subsoil water of the hill, next by a bank of earth, and next by a continuation of the system of ditches in the receiving tracts, being in fact an outlet for their flow. This ditch is laid on contour line 412. The tract C is to be fed directly from the main ditch. Tracts A and B will require separate feeders with a simple adjustment of gates for delivering the flow to one or the other as desired. This system of ditches will add from 1½ to 2 miles to the distance to which the water is to flow before reaching the surface of the larger fields; and this extension is to be bordered with willows in the same manner as the ditches in the receiving tracts. The three areas, A, B, and C, should be separated from each other by earth-banks; and an outlet draining ditch should run along the side of the railroad to a point of discharge at the southerly end of area C.

This land, lying between the contour line 412 and the railroad, is indicated as an intermediate space between the receiving ditches and the river. It is a swamp already, and a slight addition to its water will not materially alter its condition. Where it is not already covered with trees or bushes, it should be so covered. In order to secure a tolerably free distribution of the flow, each area should be divided into separate beds of greater or less width according to the distance from the feeding ditch to the draining ditch. This division may be effected by a simple rude grading along the lines indicated, barely sufficient to prevent the shallow stream from flowing from one part to the next. My belief is that the sewage will reach this land in a condition quite pure enough for immediate admission to the river. But this is a belief only, and I can point to no corresponding work in support of it. I have therefore deemed it prudent, as it is in all ways unobjectionable, to introduce this flow over the surface of a wooded swamp, which will unquestionably effect any additional purification that may be found necessary. It is only as an additional precaution, and because of the absence of actual

experience on the subject, that I have divided this tract into three separate areas for an alternation of use daily or weekly, or as often as may be found necessary; the interval between two uses of any one area being sufficient to secure the oxidation or destruction by vegetation of any remaining impurity of the effluent.

I am informed that it is not safe to provide for a daily production of sewage by the city of Worcester of less than 3,000,000 gallons. We may fairly assume that one-third of this will be lost by leakage and evaporation on the way, leaving 2,000,000 gallons per day to reach the swamp. This will be equal to about $\frac{15}{100}$ of a foot in depth every third day, or a total depth of about 200 inches per annum. That this is not an excessive amount of clarified and mainly purified sewage, to be delivered under such circumstances, may at least be inferred from the fact that the filtration ground at Kendal (England) has received and purified, since 1874, a depth of over 3,000 inches per annum of the very foul sewage of that town.*

Briefly stated, the process of purification here recommended is as follows: —

I. Separate the dry-weather sewage of the city and the early storm-washings of the sewers from the water of Mill Brook.

II. Allow the earthy matters of the sewage to subside.

III. Screen out the coarser objects.

IV. Expose the screened sewage in a thin sheet to the air during its rapid flow for a distance of 500 feet at a sharp fall.

V. Carry it at low velocity for about 10 miles through ditches bordered by rank-growing trees or bushes, — alternating to a second set of ditches as often as necessary, say once a week, so as to give each set a dry week for the aëration of the subsided matters.

VI. Spread the resultant effluent over 126 acres of wooded swamp land, giving each area two days out of three for aëration.

* Rogers Field, in the discussion of C. H. Bazalgette's paper on the Sewage Question.

Conclusion.

I believe that the method above described will be entirely efficient even for the treatment of more than 3,000,000 gallons of sewage per day. It will involve the minimum of cost for construction and maintenance, and will require the purchase of only about 165 acres of land of the lowest value.

It will, I think, fully and permanently meet the demands of the riparian population along the Blackstone River, and will satisfy, in the cheapest way the legal obligations of the city of Worcester.

Save for the product of the willows or other growth of the ditched and of the irrigated tracts, it makes no attempt at utilization. But this feature of the case can have only a secondary interest for the people of Millbury. How far it is right for that people to urge a more useful application of its sewage upon the city of Worcester is questionable.

At the same time it cannot be amiss to call attention to this means for securing a return for the inevitable outlay; and it is suggested that it would be a matter of small cost and of much promise for the city to secure a trial ground on the higher-lying garden or farming land near the screening chamber to which to force so much of the sewage as could with advantage be used on five or ten acres. It is more than possible — it is altogether probable — that such a demonstration of the value of sewage for agricultural use would lead to an extended demand for it during the growing season on the part of private cultivators, which would ultimately bring a good return, and would absorb a large part of the summer flow.

GEO. E. WARING, JUN.

NEWPORT, R.I., Dec. 5, 1881.

SKETCH SHOWING DETAILS OF MAIN CARRIER AND FEEDERS. WORCESTER, MASS.

SECTION THROUGH XY

GROUND LINE

CEDAR SWAMP

OUTLET

TOP OF BANK

FEEDER DITCH TO FEED AREA "A"

FEEDER DITCH TO FEED AREA "B"

TO FEED AREA "A" OPEN GATE No 1 AND CLOSE 2&3
" " " "B" " " " 2 " " 1&3
" " " "C" " " " 3 " " 1&2

GATE No 1

GATE No 2

GATE No 3

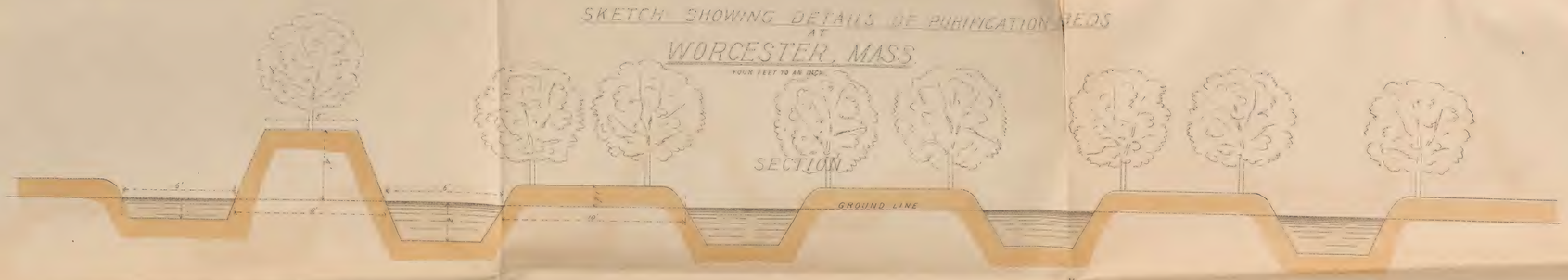
MAIN CARRIER

EMBANKMENT

INTERCEPTING DITCH

SKETCH SHOWING DETAILS OF PURIFICATION BEDS AT WORCESTER, MASS.

FOUR FEET TO AN INCH.



SPECIAL SANITARY APPENDIX.

IV. — ESTIMATE OF COST.

WORCESTER, MASS., Dec. 30, 1881.

C. D. MORSE, Esq., *Millbury, Mass.*

Dear Sir, — The following estimate is herewith submitted, of the cost of the sewage disposal works proposed by Col. George E. Waring, jun., for the diversion of the sewage of the city of Worcester from the Blackstone River: to wit, —

LAND.

30 acres purification ground, $150 per acre	$4,500 00
88 acres swamp, at $20 per acre	1,760 00
42 acres meadow, part cranberry, $100 per acre	4,200 00
Total	$10,460 00

WOODEN CONDUIT.

500 feet open wooden conduit, 20 feet wide, made of southern hard pine, floor 1¼ thick and matched	$2,700 00

The foregoing estimates are taken from your letter dated Dec. 15, 1881.

2 settling-basins, 300 feet long, 30 feet wide, built in earth, with 4 screens and 5 gates	$2,900 00

CONDUIT FROM OUTLET OF SEWER TO GROUNDS.

3,000 feet brick conduit, 36 inches in diameter, trenching and brick-work, at $4.50 per foot	$13,500 00
Extra for crossing river by an iron pipe	1,000 00
Land damage	1,500 00
Total	$16,000 00

DIVIDING CONDUITS IN MILL BROOK.

From the outlet of the sewer at Quinsigamond to Cambridge Street, a distance of 4,200 feet, a 36-inch cast-iron pipe has been estimated, because the Piedmont sewer enters the main canal at the same level as the bed of the canal, and it is not practical to carry the sewage to the side of the canal.

641 tons 36-inch pipe, at $45	$28,845 00
Laying 4,200 feet pipe, at $2	8,400 00
Extra for connections	2,000 00
5,000 cubic yards concrete in 10,000 feet of Mill Brook, north of Cambridge Street, at $10 per cubic yard	50,000 00
Extra for irons and connections	3,000 00
Total	$92,245 00

ESTIMATE OF COST.

Reparation of Swamp Areas.

13,000 feet main carrier.
6,000 feet feeder to area A.
3,000 feet feeder to area B.

22,000 feet main carrier and feeder.
13,500 feet intercepting ditch to carry off surface-water.

35,500 feet ditches as above, 36,000 cubic yards' excavation, at 30 cts.	$10,800 00
6,000 feet drain ditch next railroad, at $1.25	7,500 00
4,000 feet separating dykes between swamp areas	2,000 00
48 small gates and fixtures	500 00
3 large gates and fixtures	150 00
Total	$20,950 00

Purification Areas.

Grading of 30 acres of ground preparatory for the trenching, and making 15 miles trenches, estimated to take 120,000 cubic yards of earth-work, at 35 cts.	$42,000 00
Willows	500 00

Summary.

Land	$10,460 00
Wooden conduit	2,700 00
Settling-basins	2,900 00
Brick conduit	16,000 00
Dividing conduit in Mill Brook	92,245 00
Reparation of swamp area	20,950 00
Purification area	42,000 00
Willows	500 00
Add for engineering and contingencies	18,745 00
Total estimated cost	$206,500 00

Respectfully submitted.

PHINEHAS BALL,
SIMPSON C. HEALD,
Civil Engineers.
AMOS PIKE,
Contractor.